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**Type of Organization:** College or University

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**Project Title:** Use of Remote Sensing To Model Organic Contamant Cycling

**Project Category:** Emerging Issues

**Rank by Organization (if applicable):** 0

**Total Funding Requested ($):** 260,687 **Project Duration:** 2 Years

**Abstract:**

Storm surges and runoff have important implications for contaminant cycling, biotic interactions, and biogeochemical exchange. Yet these events are difficult to track using conventional shipboard sampling methods alone, due to the transient and unpredictable nature of events. Moreover, the scale and magnitude of episodic events in the Great Lakes suggests valuable research applications of satellite remote sensing to detect changes in sediment loadings and to track their transport before, during, and after episodic events. Recent applications of satellite and in situ observations are clarifying the importance of sediment resuspension and river discharges in southern Lake Michigan, and are beginning to identify dominant processes. Satellite tracking of coastal plumes over a seven year period from 1992 to 1998 revealed surprising high frequency of events, although the areal extent and relative magnitude in terms of mass of resuspended sediment varied greatly from event to event. Budd and K.C. Hornbuckle (U-Iowa) hypothesize that remotely sensed imagery may facilitate more accurate estimates of mass fluxes of certain contaminants by providing daily estimates of sediment concentrations for the entire water body. We will investigate this hypothesis with special attention to the contributions of heavily contaminated sediments from embayments, tributaries and from coastal erosion. Previous work (Bodgan et al. 1999) has indictated that intense storms drive large inputs of mineral sediments that are low in organic contaminants. Resuspension of contaminated sediments near industrial centers, although small contributors to total particulate mass loading, may be very large sources of contaminants to the open lake. We will couple satellite images, interpolated to describe daily loadings, with ship-based measurements to assess the relative importance of these two sources of sediments on total loading of persistent, bioaccumulating and toxic organic pollutants.

**Geographic Areas Affected by the Project**

**States:**

- [x] Illinois
- [x] Indiana
- [x] Michigan
- [ ] Minnesota
- [ ] New York
- [ ] Pennsylvania
- [x] Wisconsin
- [ ] Ohio

**Lakes:**

- [ ] Superior
- [ ] Huron
- [x] Michigan
- [ ] Erie
- [ ] Ontario
- [ ] All Lakes

**Geographic Initiatives:**

- [ ] Greater Chicago
- [ ] NE Ohio
- [x] NW Indiana
- [ ] SE Michigan
- [ ] Lake St. Clair

**Primary Affected Area of Concern:** Grand Calumet River/IHC, IN

**Other Affected Areas of Concern:**

***For Habitat Projects Only:***

**Primary Affected Biodiversity Investment Area:**

**Other Affected Biodiversity Investment Areas:**

**Problem Statement:**

Storm surges and runoff have important implications for contaminant cycling, biotic interactions, and biogeochemical exchange. Moreover periodic sediment resuspension can be a major route of mobilization of in situ toxic materials. Yet these events are difficult to track using conventional shipboard or shorebased sampling methods alone, due to the transient and unpredictable nature of events. The scale and magnitude episodic events in the Great Lakes suggests valuable research applications of satellite remote sensing to detect changes in sediment concentrations and to track their transport before, during, and after episodic resuspension and runoff events.

Periodic seasonal and interannual storm events can produce extreme gradients in sediment concentrations, nutrients, and species composition. Vertical and horizontal patterns may form, evolve, and decay during a single event or season. However, little is known about
the movement of resuspended sediments, the temporal progression of events, and the time course of water mass and subsequent trophic stimulation. How frequent are resuspension events and riverine pulses and to what degree are sediments, contaminants, and nutrients physically transported horizontally or vertically?

Evaluating the impact of episodic resuspension and runoff is deceptively complicated. Circulation patterns, suspended sediments, and nutrient loads can be highly variable spatially and temporally and are dependent on numerous factors. Shipboard sampling provides very high quality measurements of many parameters simultaneously, with the ability to characterize subsurface features in the water column. However, logistical difficulties prohibited direct study of these events because researchers were hard pressed to obtain large-scale, frequently-sampled snapshots of lake surfaces (i.e., truly synoptic surveys).

To address the problem, a first step is to determine the incidence and persistence of events. A second step is to clarify the details of particle transport and subsequent contaminant transformations. Recent applications of satellite and in situ observations are clarifying the
importance of sediment resuspension and river discharges, and are beginning to identify dominant processes. Although voiced several times (e.g., Hecky and McCullough 1984; Budd et al. 1998), few studies of Great Lakes have utilized this technology. One notable exception was the pioneering work of Mortimer (1988), who observed episodic resuspension events in southern Lake Michigan in CZCS images from 1977 and 1978. More recent satellite tracking of southern Lake Michigan coastal plumes over a seven year period from 1992 to 1998 (Warrington et al. 1999; Budd et al. in preparation), revealed surprising high frequency of events, although the areal extent and relative magnitude in terms of mass of resuspended sediment varied greatly from event to event.

J.W. Budd (MTU) and K.C. Hornbuckle (U-Iowa) hypothesize that remotely sensed imagery may facilitate more accurate

estimates of mass fluxes of certain contaminants by providing daily estimates sediment concentrations for the entire water body. We will investigate this
hypothesis with special attention to the contributions of heavily deposited sediments from embayments, tributaries and from coastal erosion. Previous work (Bodgan et al. 1999) has indictated that intense storms drive large inputs of mineral sediments that are low in
organic contaminants. Resuspension of contaminated sediments near industrial centers, although small contributors to total particulate mass loading, may be very large sources of contaminants to the open lake. We will couple satellite images, interpolated to describe daily
loadings, with in situ measurements to assess the relative importance of these two sources of sediments on total loading of persistent, bioaccumulating and toxic organic pollutants.

**Proposed Work Outcome:**

Our objectives are to 1) document the incidence, magnitude, and persistence of episodic resuspension and runoff events at a variety of temporal and spatial scales using satellite-derived water quality estimates; 2) provide the first synoptic "observations" of major sediment resuspension and runoff events, as well as estimates of the mass concentrations of sediment in the water column; and, 3) combine extensive field data (from the Lake Michigan Mass Balance (samples collected in 1994-95), the EEGLE study (samples collected in 1997-2000), and other published field data) and satellite-derived measurements as input to modeling the cycling of contaminants in the air and water.

Task 1. Provide daily estimates of stallite-derived remote sensing reflectance (RRS, a surrogate for turbidity), temperature and chlorophyll (where applicable) from the AVHRR (Advanced Very High Resolution Radiometer), SeaWiFS (Sea-viewing Wide Field-of-View Sensor, MODIS (Moderate Resolution Imaging Spectroradiometer), and Landsat
satellites.

We will use state-of-the-art image processing protocols, including a NASA-approved near-coastal atmospheric correction routine with SeaWiFS and MODIS imagery for Case II waters, to produce an accessible (via the WWW and other means), internally consistent database of remotely sensed data. We will validate the satellite-derived water quality estimates using shipboard sampling data acquired under ongoing EEGLE (Episodic
Events Great Lakes Experiment) and KITES (Keweenaw Interdisciplinary Transport Experiment in Superior) projects.

Task 2. Use a statistically-based objective interpolation procedure to fill in temporal gaps caused by cloud cover in the satellite data. The proposed method, called Objective Analysis, which has been used successfully in a variety of oceanographic studies (e.g., Bretherton et
al. 1976, Carter and Robinson 1987, Mariano and Brown 1992, Ransibrahmanakul 1996), is based on the Gauss-Markoff theorem (Liebelt 1967). Since sediment loads are highly variable both temporally and spatially, more accurate daily estimates of suspended sediment
concentrations will greatly improve input to the modeling experiments.

Task 3. Compile measurements of bioaccumulating, persistent and toxic compounds in the water and sediments of southern Lake Michigan. Data from the Lake Michigan Mass Balance, the EEGLE study, and other published data will be used. The data will be plotted on time and space 'maps' to determine the time and location that is represented by each sample.

Task 4. Extrapolate and/or interpolate concentrations of PBTs associated with suspended sediments using highly resolved spatial satellite images of suspended sediments in southern Lake Michigan.

Task 5. Estimate the mass of PBTs associated with suspended sediments of different origins. For example, we will use measurements of chemical concentrations coupled with the satellite images to estimate the mass export of BPTs from 1) the Calumet River suspended sediments, 2) from coastal erosion, and 3) from autochthonous (in-lake) sources of suspended particulates.

No new samples will be collected as part of this study, although samples collected under the EEGLE program, will be analyzed for PBTs not covered under EEGLE.

References:

Bretherton, F.P., R.E. Davis, and C.B. Fandry. 1976. A technique for objective analysis and design of oceanographic experiments applied to MODE-73. Deep-Sea Research 23: 559-582.

Bogdan, J.J., K.C. Hornbuckle, and J.W. Budd. 1999. Increased atmospheric deposition of SOCs due to large-scale sediment resuspension in southern Lake Michigan. 3rd EEGLE/KITES Workshop. Minneapolis, MN. Oct 27-30, 1999.

Budd, J.W., W.C. Kerfoot, A.L. Maclean, 1998. Documenting complex surface temperature patterns from Advanced Very High Resolution Radiometer (AVHRR) Imagery of Saginaw Bay, Lake Huron. J. Great Lakes Res. 24(2): 582-594.

Budd, J.W., V. Ransibrahmanakul, R.P. Stumpf, and D.S. Warrington. In Preparation. Chlorophyll and sediment retrievals using SeaWiFS imagery to monitor episodic events in the Great Lakes.

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Liebelt, P.B. 1967. An Introduction to Optimal Estimation. Addison-Wesley Publishing Company, Reading, Massachusetts.

Mariano, A.J., and O.B. Brown. 1992. Efficient objective analysis of dynamically heterogeneous and nonstationary fields via the parameter matrix. Deep-Sea Research 39: 1255-1271.

Mortimer, C.H. 1988. Discoveries and testable hypotheses arising from Coastal Zone Color Scanner imager of southern Lake Michigan. Limnol. Oceanogr. 33(2):203-226.

Ransibrahmanakul, V. 1996. Variability of Eddy Heat Fluxes Over the Northwestern Gulf of Mexico. A Ph.D. dissertation, Louisiana State University, Baton Rouge.

Warrington, D.S., Budd, J.W., R.P. Stumpf, V. Ransibrahmanakul, 1999. Remote sensing of Great Lakes Water Quality using SeaWiFS imagery. ASLO 1999 Aquatic Sciences Meeting February 1-5, 1999, Santa Fe, NM, p. 187.

| Project Milestones: | Dates: |
|---|---|
| Design satellite interpolation protocol | 02/2001 |
| Validate sat. parameters w/ in situ data | 06/2001 |
| Fill-in temporal & spatial gaps RS data | 12/2001 |
| Complete chemical analyses | 12/2001 |
| Combin chemical & satellite for modeling | 12/2001 |
| Est. PBT mass assoc. w/ sediments | 06/2001 |
| Complete model sediment/chemical fluxes | 02/2001 |
| Submit manuscript(s) | 07/2002 |

☐ Project Addresses Environmental Justice

**If So, Description of How:**

☐ Project Addresses Education/Outreach

**If So, Description of How:**

**Project Budget:**

| | Federal Share Requested ($) | Applicant's Share ($) |
|---|---|---|
| **Personnel:** | 44,750 | 20,000 |
| **Fringe:** | 9,975 | 0 |
| **Travel:** | 2,400 | 0 |
| **Equipment:** | 7,500 | 0 |
| **Supplies:** | 12,050 | 12,000 |
| **Contracts:** | 128,000 | 0 |
| **Construction:** | 0 | 0 |
| **Other:** | 0 | 0 |
| **Total Direct Costs:** | 204,675 | 32,000 |
| **Indirect Costs:** | 56,012 | 0 |
| **Total:** | 260,687 | 32,000 |
| **Projected Income:** | 0 | 0 |

**Funding by Other Organizations (Names, Amounts, Description of Commitments):**

Budd:

Michigan Sea Grant, "Episodic Events and Trophic Pulses: Estimating Surface Chlorophyl Concentrations and Transport Using SeaWiFS and MODIS Imagery" PI with three others. $30,000 Program Development Funds from 3/1/00 to 12/31/00.

NSF/NOAA, "EEGLE: Episodic Events: Great Lakes Experiment: Understanding the Historical Magnitude of Spring Turbidity Plumes in Southern Lake Michigan, Co-PI with two others, $599,782 total grant, $426,956 to JWB from 9/1/97 to 8/31/02.

NSF/NOAA, "KITES: Keweenaw Interdisciplinary Transport Experiment on Superior", Co-PI with nine others, $4.7M total grant, $424,000 to JWB from 9/1/97 to 8/31/02.

Hornbuckle:

-U.S. Environmental Protection Agency, Great Lakes National Program Office. "Study of Organic Contaminants in Air and Water in Conjunction with Episodic Events - Great Lakes Experiment." Jan. 1, 1998 to Feb 4. 2001: $364,000.

-U.S. Environmental Protection Agency, Great Lakes National Program Office. "Atmospheric Loading of PCBs, Trans-nonaclor, Atrazine, Nitrogen and Phosphorous to Lake Michigan." Oct. 1, 1996 to Sept 30, 1999: $251,000. (with J.V. DePinto - Co-PI).

-National Science Foundation Faculty Early Career Development (CAREER) Program. "Dynamics of Gas-Phase Persistent Organic Chemicals: An Investigation of the Effect of Climate using a Controlled Chamber." Sept. 1, 1997 through Aug. 30, 2001: $200,000.

-Center for Global and Regional Environmental Research (CGRER). "Design and Installation of the Iowa Atmospheric Measurement Station (IA-AMS)." August 1999 - August, 2000. $20,000. (with W.E. Eichinger Co-PI)

-Unversity of Iowa Carver Scientific Research Initiative Grant Program. "Stage I Planning For a Trinational Atmospheric Deposition Network for Persistent Organic Pollutants." May, 1999 - May 2000. $15,000.

**Description of Collaboration/Community Based Support:**

As Co-PI, Dr. Budd leads the remote sensing teams for the EEGLE and KITES projects. Dr. Budd is currently PI or Co-PI on seven grants, with total funding in excess of $1.22M (JWB portion, 1992 to present). Since receiving her Ph.D. in 1997,

four papers have been accepted and/or published in peer-reviewed journals and two more are in review. Dr. Budd currently advises four graduate students.

Dr. Hornbuckle has been involved in Great Lakes air toxics research since working on the Green Bay Mass Balance project starting in 1989. She has published fifteen peer-reviewed papers on air/water exchange and air/terrestrial exchange of air toxics (PAHs, PCBs and other chlorinated organics), four submitted on work completed as part of the Lake Michigan Mass Balance. Dr. Hornbuckle is an active member of the International Joint Commission's (IJC) Science Advisory Board and a liaison to the IJC's International Air Quality Advisory Board. Dr. Hornbuckle currently advises six graduate students.